ARTICLE

The Risk of Death by Age, Sex, and Smoking Status in the United States: Putting Health Risks in Context

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Background   To make sense of the disease risks they face, people need basic facts about the magnitude of a particular risk and how one risk compares with other risks. Unfortunately, this fundamental information is not readily available to patients or physicians. We created simple one-page charts that present the 10-year chance of dying from various causes according to age, sex, and smoking status.

Methods   We used the National Center for Health Statistics Multiple Cause of Death Public Use File for 2004 and data from the 2004 US Census to calculate age- and sex-specific death rates for various causes of death. We then combined data on smoking prevalence (from the National Health Interview Survey) and the relative risks of death from various causes for smokers vs never smokers (from the American Cancer Society's Cancer Prevention Study-II) to determine age-, sex-, and smoking-specific death rates. Finally, we accumulated these risks for various starting ages in a series of 10-year life tables. The charts present the 10-year risks of dying from heart disease; stroke; lung, colon, breast, cervical, ovarian, and prostate cancer; pneumonia; influenza; AIDS; chronic obstructive pulmonary disease; accidents; and all causes.

Results   At all ages, the 10-year risk of death from all causes combined is higher for men than women. The effect of smoking on the chance of dying is similar to the effect of adding 5 to 10 years of age: for example, a 55-year-old man who smokes has about the same 10-year risk of death from all causes as a 65-year-old man who never smoked (ie, 178 vs 176 of 1000 men, respectively). For men who never smoked, heart disease death represents the single largest cause of death from age 50 on and the chance of dying from heart disease exceeds the chances of dying from lung, colon, and prostate cancers combined at every age. For men who currently smoke, the chance of dying from lung cancer is of the same order of magnitude as the chance dying from heart disease and after age 50 it is about 10 times greater than the chance of dying from prostate or colon cancer. For women who have never smoked, the magnitudes of the 10-year risks of death from breast cancer and heart disease are similar until age 60; from this age on, heart disease represents the single largest cause of death. For women who currently smoke, the chance of dying from heart disease or lung cancer exceeds the chance of dying from breast cancer from age 40 on (and does so by at least a factor of 5 after age 55).

Conclusion   The availability of simple charts with consistent data presentations of important causes of death may facilitate discussion about disease risk between physicians and their patients and help highlight the dangers of smoking.

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It is difficult to read a newspaper or magazine, watch television, or surf the Internet without encountering a multitude of competing messages about the health risks one faces. At best, the sheer volume of risk information confuses some people ("which risk should I pay attention to?"). More concerning, however, is that it may lead other people to make unwise choices (eg, deciding that prostate cancer screening is more important than stopping smoking) or to become cynical about health risks in general ("why pay attention at all if everything is so dangerous?").

The problem with risk information is that it is often incomplete and provided without context. For example, a 2006 press release from the Food and Drug Administration that announced the approval of a cervical cancer vaccine stated that "there are 3,700 deaths attributed to cervical cancer in the United States each year" (1),

and a disease advocacy group Web site that highlights the danger of prostate cancer stated that "in 2007, more than 27000 men will die from the disease" (2). Although both messages employed a common communication tactic—using large numbers to capture

CONTEXT AND CAVEATS

Prior knowledge
The information that people receive about their risk of disease is often incomplete because it does not address the probability of dying from the specific disease over a defined time period, nor does it put the risk into the context of other important health risks.

Study design
National census and health data for 2004 were used to create simple one-page charts that present the 10-year chance of dying, according to age, sex, and smoking status, from heart disease; stroke; lung, colon, breast, cervical, ovarian, and prostate cancer; pneumonia; influenza; AIDS; chronic obstructive pulmonary disease; accidents; and all causes.

Contribution
At all ages, the 10-year risk of death from all causes combined is higher for men than women. The effect of smoking on the chance of dying is similar to the effect of adding 5 to 10 years of age. For men who never smoked, heart disease death represents the single largest cause of death from age 50 on. For men who currently smoke, the chance of dying from lung cancer is of the same order of magnitude as the chance of dying from heart disease from age 60 on, and after age 50, it is 10 times greater than the chance of dying from prostate or colon cancer. For women who never smoked, the 10-year risks of death from breast cancer and heart disease are similar until age 60; from this age on, heart disease represents the single largest cause of death. For women who currently smoke, the chance of dying from heart disease or lung cancer exceeds the chance of dying from breast cancer from age 40 on.

Implications
The availability of simple charts with consistent data presentations of important causes of death may facilitate discussion about disease risk between physicians and their patients and help highlight the dangers of smoking.

Limitations
The mortality data that were used to calculate cause-specific death rates were derived from death certificates and are only as good as the death certificates. Relative risks of death from various causes were from the American Cancer Society's Cancer Prevention Study-II, which represent a single—albeit very large—cohort study. Risk estimates were not personalized beyond age, sex, and smoking status.

the reader's attention—neither provided a complete statement of risk, that is, one that addresses the probability of dying from the specific cancer over a defined time period. And neither message put this risk in the context of other important health risks, such as the risk of dying from heart disease or lung cancer (the risks of both are substantially higher than those for cervical or prostate cancer). The point of presenting these examples is not to minimize the tragedies of cervical or prostate cancer deaths but rather to highlight the importance of providing the information needed to make risk messages useful.

Useful messages about health risks should address two questions: how big is my risk and how does this risk compare with other risks? Approximately 5 years ago, we published a set of risk charts that were intended to address both of these questions (3). The charts presented estimates of an individual's chance of dying within

the next 10 years from a variety of causes according to his or her age, sex, and smoking status—arguably the three characteristics that have the most important influence on mortality. The charts provided context by allowing people to compare their chances of dying at different ages across disease categories and in the context of all-cause mortality. These charts have been posted on the Web site of a major association of primary care physicians for point-of-care use by physicians (4), and they were published by a national newspaper (which reported that the charts inspired an editor of a major medical journal to quit smoking) (5). We now update these charts with a revised algorithm that takes into account a valid methodologic concern about our original calculations (6) and incorporates the most recent national mortality data available.

Methods

Overview

Our goal was to create simple one-page charts that put disease risk in context by placing the 10-year chance of dying from various causes side by side. To account for the influence of sex, we created separate charts for men and women. To account for the influence of age on mortality, the charts provide separate estimates for 5-year increments of age. To account for the influence of smoking, the charts provide separate estimates for people who currently smoke, people who used to smoke, and people who never smoked.

Chart Design

To make the charts easy to understand, we limited the amount of data presented and paid particular attention to their format. The charts present data on the 10-year chance of dying to provide a reasonable window into the future; to avoid data overload and to limit each chart to a single page, the charts present the starting age in 5-year increments (ie, age 35 years, 40 years, 45 years, and so on up to age 75 years) rather than every year of age. We represented the mortality data as counts with a stable denominator (eg, 3 in 1000, 10 in 1000) rather than as proportions or rates because some evidence (7–10) suggests that this format is easiest to understand. To further simplify the appearance of the charts, we rounded the number of deaths to the nearest whole number and shaded cells in which the death rate was less than 1 per 1000. Finally, to help clarify the contribution of each individual cause of death, the charts include the chance of dying from all causes combined.

Selected Causes of Death

The risk charts include the most common causes of death (eg, heart disease, lung cancer) as well as causes of death that have received particular attention in the media (eg, AIDS, ovarian cancer). The charts present 10 causes of death for men and 12 for women. Nine of the causes of death apply to both sexes: heart disease, stroke, lung cancer, colon cancer, pneumonia, flu, AIDS, chronic obstructive pulmonary disease (COPD), and accidents. The sex-specific causes are prostate cancer (for men) and breast, cervical, and ovarian cancer (for women).

We grouped individual causes of death into disease categories using standard National Center for Health Statistics (NCHS) groupings [ie, based on the list of the 358 most common causes
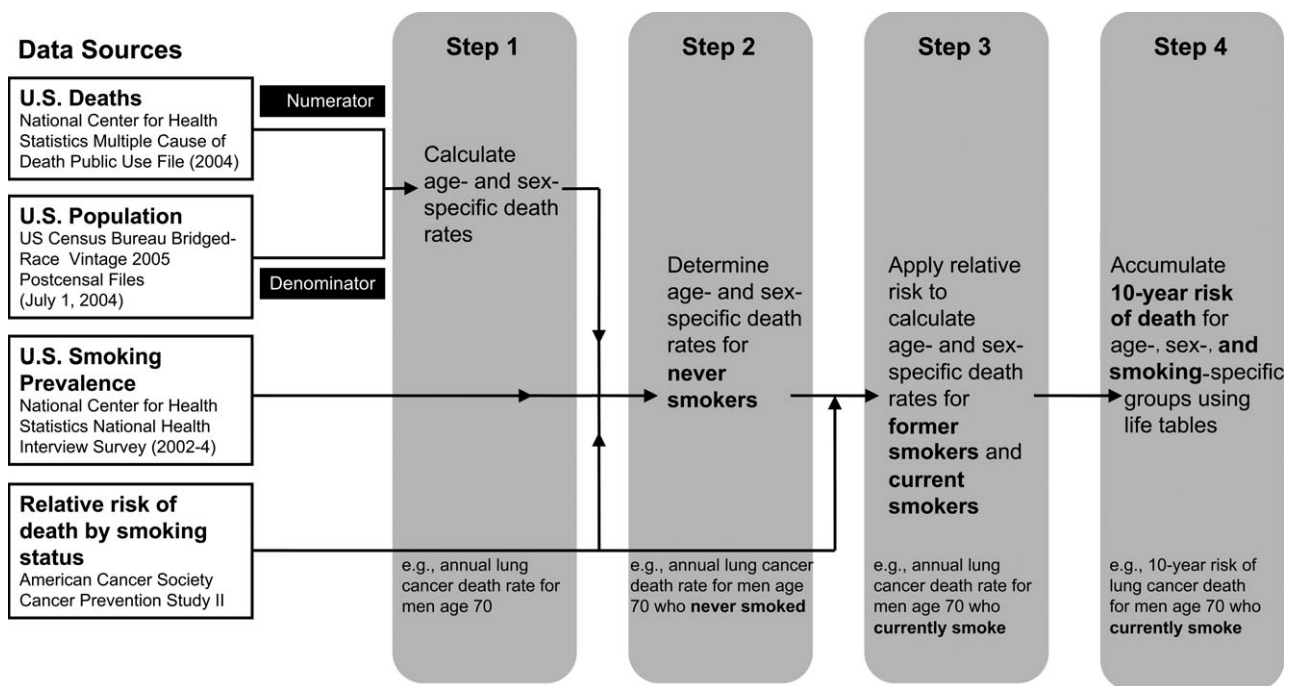
Figure 1. Data sources and steps used to create the risk charts.

of death (11); see Appendix 1]. Our only departure from the NCHS groupings was the creation of the category "heart disease," which includes deaths from acute and chronic ischemic heart disease and associated complications (eg, congestive heart failure and arrhythmia); the heart disease category does not include other heart disease deaths (eg, endocarditis, valvular disease, and pericarditis).

Data Sources and Calculations

Figure 1 summarizes our data sources and the four calculation steps we used to produce the risk charts.

Step 1: Calculate Age-, Sex-, and Cause-Specific Death Rates. We calculated death rates for each sex, for each year of life (from age 35 through age 84), for all causes combined, and for each selected cause (ie, more than 1200 age-, sex-, and cause-specific rates). These age-, sex-, and cause-specific annual death rates for 2004 were calculated using the following equation:

Age-, sex-, cause-specific death rate
$= \mathrm{Deaths_{TOTAL}}/\mathrm{N_{TOTAL}}$
= Age- and sex-specific number of deaths from cause X in 2004/ Age- and sex-specific population in 2004.

We used the NCHS Multiple Cause of Death Public Use File for 2004 to obtain the numerator, that is, the number of deaths from each selected cause (and from all causes combined) among individuals of a specific age and sex (12). The file contains information on all deaths in the United States and is based on death certificates completed by each state [all states require the reporting of all deaths, and it is believed that more than 99% of all deaths in the United States are registered by the states (13)]. A death certificate may list multiple causes of death; these causes

are translated at NCHS into codes that are enumerated in the *International Classification of Diseases, Tenth Revision* (available at http://www.who.int/classifications/icd/en/). A computer program at NCHS assigns the underlying cause of death from the multiple causes listed on each certificate. The risk charts are based on the underlying cause of death. We used data from the 2004 US Census to obtain the denominator, that is, the estimated midyear (July 1, 2004) US resident population for each year of age and sex (14).

Step 2: Determine Age-, Sex-, and Cause-Specific Death Rates for Never Smokers. The most challenging task of our analysis was to apportion these death rates according to smoking status. As recommended by Bach and Schrag (6), we modified our original approach for estimating risks by considering current smokers, former smokers, and never smokers as distinct groups. We reasoned that each age-, sex-, and cause-specific death rate is the weighted average of the age-, sex-, and cause-specific death rates for never smokers (NS), former smokers (FS), and current smokers (CS), where the weights reflect the proportion of the population in each group:

Age-, sex-, cause-specific death rate
$= (\% \text{ NS} \times \mathrm{rate_{NS}}) + (\% \text{ FS} \times \mathrm{rate_{FS}}) + (\% \text{ CS} \times \mathrm{rate_{CS}})$.

The death rates in the two smoking groups—that is, current smokers and former smokers—were derived by multiplying the never smokers death rate by the relative risks (RRs) associated with former ($\mathrm{RR_{FS/NS}}$) and current ($\mathrm{RR_{CS/NS}}$):

Age-, sex-, cause-specific death rate
$= (\% \text{ NS} \times \mathrm{rate_{NS}}) + \% \text{ FS} \times (\mathrm{rate_{NS}} \times \mathrm{RR_{FS/NS}}) + \% \text{ CS} \times (\mathrm{rate_{NS}} \times \mathrm{RR_{CS/NS}})$.

We then used an algebraic transformation (see Appendix 2) to solve the following equation for the age-, sex-, and cause-specific death rates in never smokers:

Age-, sex-, cause-specific death rate$_{NS}$
= Deaths$_{TOTAL}$/{N$_{TOTAL}$ × [% NS + (% FS x RR$_{FS./NS}$) + (% CS x RR$_{CS./NS}$)]}.

To solve this equation, we needed to know the prevalence of smoking and the relative risk of death according to smoking status. We obtained the prevalence of smoking by sex and age (age categories: 18–24, 25–44, 45–64, 65–74, and ≥75 years) from the National Health Interview Survey, 2002–2004 (15). We used the Centers for Disease Control and Prevention's definitions of smoking status (16): never smokers are people who have smoked fewer than 100 cigarettes in their lifetime, former smokers are people who do not smoke now but smoked at least 100 cigarettes in the past, and current smokers are people who smoke now and have smoked at least 100 cigarettes in their lifetime.

The second input for the calculation was the relative risk of death according to smoking status. We sought sex-specific relative risks of death for former and current smokers (vs never smokers) dying from diseases with well-established associations with smoking (heart disease, stroke, COPD, lung cancer, pneumonia, and influenza) and from all causes combined. These were obtained from the American Cancer Society's Cancer Prevention Study II (CPS-II), a prospective cohort study of more than 1.2 million US adults aged 30 years or older that began in 1982 (17). Because these relative risks were provided for only very broad age categories, we requested and obtained further refined, age-specific relative risks (in 5-year age categories beginning at age 35) from CPS-II (M. Thun, MD, personal communication).

Step 3: Calculate Age-, Sex-, and Cause-Specific Death Rates for Former and Current Smokers. We calculated age-specific annual death rates for former smokers by multiplying the age-specific risk for never smokers by the relative risk of death for former vs never smokers. Similarly, we calculated age-specific annual death rates for current smokers using the relative risk of death for current vs never smokers.

Step 4: Accumulate the 10-Year Risks of Death for Each Cause for Age-, Sex-, and Smoking-Specific Groups. We used previously described methods (18) to create separate 10-year life tables for each specific cause of death and all causes combined for male and female never, former, and current smokers in each of the nine age categories, for a total of 648 life tables (ie, each of the 648 numbers displayed in the four charts reflect a unique life table). For each year of age, we multiplied the number of people who were alive at the beginning of the age interval by the disease-specific death rate to obtain the number of disease-specific deaths. Likewise, we calculated the number of deaths from all causes in the age interval by using the all-cause death rates. We subtracted deaths from all causes from the number of people who were alive at the beginning of the interval to obtain the number of people alive at the beginning of the next age interval. We then summed the number of deaths over 10 years to obtain the 10-year probability of death for each age in the risk chart:

Cause-specific 10-year risk of death$_{age-,\ sex-,\ smoking-specific\ group}$
= [$\sum_{i=1}^{10}$ (Alive$_{i-1}$ – All Death$_{i-1}$) × Disease death rate$_i$] / Starting population (100 000).

For example, we applied the all-cause death rate for a 70-year-old man who never smoked to calculate the total number of deaths after 1 year in a cohort of 100 000 men aged 70 years (ie, 1990 deaths). We then subtracted this number from 100 000 to obtain the number of survivors (ie, of the original 100 000 men aged 70 years, how many reached age 71). These 98 010 survivors made up the population at risk for death in the subsequent year. We then applied the all-cause death rate calculated for 71-year-old men to determine the number of deaths over the next year and repeated the process through the 10th year. In this way, we defined the population at risk for death at the beginning of each of 10 years. We then applied the age-specific death rate for each individual cause of death to the population at risk at the beginning of each year to get the number of disease-specific deaths. We obtained the 10-year chance of dying from each cause by adding the number of deaths in each of the 10 years divided by the starting population (100 000). For simplicity, we express this risk as per 1000. (A completed example for a current smoker's risk of lung cancer death and death from all causes combined is shown in Appendix 2.)

Sensitivity Analysis
The relative risks from CPS-II have been criticized—most notably by the tobacco industry—because they were not adjusted for potentially confounding socioeconomic characteristics. In response to these criticisms, Thun et al. (19) pointed out that CPS-II participants, regardless of their smoking history, were fairly homogeneous, and they showed that adjusting for behavioral and other demographic factors only minimally attenuated the relative risks for smoking. To avoid overestimating the association between smoking and death, we "adjusted" our age-specific relative risks by applying the average attenuation effect noted in the Thun et al. (19) analysis (on average, the association between current smoking and the various causes of mortality was reduced by 10%, eg, from relative risk of 2.0 to a relative risk of 1.8). We assessed the effect of even greater adjustment (to allow for the possibility of substantial residual confounding) by conducting a sensitivity analysis.

Results

Risk Charts for Men
Figure 2 is the risk chart for men who have never smoked and men who currently smoke. In each age category, the top row shows risks for never smokers and the bottom row shows risks for current smokers. For men who have never smoked, accidents are the single largest cause of death until age 45, at which age accidents tie with heart disease as the largest cause of death; from age 50 on, the single largest cause of death is heart disease. Within each age group of never smokers, the chances of dying in the next 10 years from lung, colon, and prostate cancer are of a similar order of magnitude until about age 70 and do not exceed that for accidental deaths until after age 65.

For men who currently smoke, the chance of dying from heart disease exceeds the chance of dying from each of the other causes until age 60, when it is surpassed by the chance of dying from lung

Risk Chart for Men (current and never smokers)*

Find the line closest to your age and smoking status. The numbers tell you **how many of 1000 men will die in the next 10 years from...**

Age	Smoking status	Vascular Disease — Heart Disease	Stroke	Cancer — Lung	Colon	Prostate	Infection — Pneumonia	Flu	AIDS	Lung Disease — COPD	Accidents	All Causes Combined
35	Never smoker	1	1						2		5	15
	Smoker	**7**	**1**	**1**		Less than 1 death			**2**		**5**	**42**
40	Never smoker	3	1	1	1				2		6	24
	Smoker	**14**	**2**	**4**	**1**				**2**	**1**	**6**	**62**
45	Never smoker	6	1	1	1				2		6	35
	Smoker	**21**	**3**	**8**	**1**	**1**			**2**	**1**	**6**	**91**
50	Never smoker	11	1	1	2	1	1		1		5	49
	Smoker	**29**	**5**	**18**	**2**	**1**	**1**		**1**	**3**	**5**	**128**
55	Never smoker	19	3	1	3	2	1		1	1	5	71
	Smoker	**41**	**7**	**34**	**3**	**1**	**2**		**1**	**7**	**4**	**178**
60	Never smoker	32	5	2	5	3	2		1	1	5	115
	Smoker	**56**	**11**	**59**	**5**	**3**	**3**		**1**	**16**	**4**	**256**
65	Never smoker	52	9	4	8	6	3			3	6	176
	Smoker	**74**	**16**	**89**	**7**	**6**	**5**			**26**	**5**	**365**
70	Never smoker	87	18	6	10	12	6			5	7	291
	Smoker	**100**	**26**	**113**	**9**	**10**	**9**			**45**	**6**	**511**
75	Never smoker	137	32	8	13	19	11			6	11	449
	Smoker	**140**	**39**	**109**	**11**	**15**	**16**			**60**	**9**	**667**

*A never smoker has smoked fewer than 100 cigarettes in his life and a current smoker has smoked at least 100 cigarettes or more in his life and smokes (any amount) now. The numbers in each row do not add up the chance of dying from all causes combined because there are many other causes of death besides the ones listed here.

Figure 2. Risk chart for men who currently or have never smoked. The chart indicates the number of men—current smokers (**bold type**) and never smokers—per 1000 who will die from various diseases and from all causes combined during the next 10 years, beginning at the indicated age. **Shaded area** indicates age group and disease combinations with less than 1 death per 1000. COPD = chronic obstructive pulmonary disease.

Risk Chart for Men (former smokers)*

Find the line closest to your age. The numbers tell you **how many of 1,000 men will die in the next 10 years from...**

Age	Vascular Disease — Heart Disease	Stroke	Cancer — Lung	Colon	Prostate	Infection — Pneumonia	Flu	AIDS	Lung Disease — COPD	Accidents	All Causes Combined
35	2	1	1		Less than 1 death			2		5	23
40	4	1	1	1	1			2		6	34
45	10	1	4	1	1	1		2	1	6	49
50	17	2	7	2	1	1		1	2	5	72
55	27	3	13	3	2	1		1	7	4	107
60	41	6	22	5	3	2		1	12	5	166
65	60	11	32	7	6	4			20	5	247
70	90	18	44	10	11	7			34	7	362
75	135	31	53	12	18	14			50	11	519

* A former smoker has smoked at least 100 cigarettes in his life but no longer smokes. The numbers in each row do not add up the chance of dying from everything combined, because there are many other causes of death besides the ones listed here.

Figure 3. Risk chart for men who used to smoke. The chart indicates the number of male former smokers per 1000 who will die from various diseases and from all causes combined during the next 10 years, beginning at the indicated age. **Shaded area** indicates age group and disease combinations with less than 1 death per 1000. COPD = chronic obstructive pulmonary disease.

Risk Chart for Women (current and never smokers)*

Find the line closest to your age and smoking status. The numbers tell you **how many of 1,000 women will die in the next 10 years from...**

Age	Smoking status	Vascular Disease — Heart Disease	Stroke	Cancer — Lung Cancer	Breast Cancer	Colon Cancer	Ovarian Cancer	Cervical Cancer	Infection — Pneumonia	Flu	AIDS	Lung Disease — COPD	Accidents	All Causes Combined
35	Never smoker	1			1						1		2	14
35	**Smoker**	**1**	**1**	**1**	**1**						**1**		**2**	**14**
40	Never smoker	1			2	1					1		2	19
40	**Smoker**	**4**	**2**	**4**	**2**						**1**	**1**	**2**	**27**
45	Never smoker	2	1	1	3	1	1				1		2	25
45	**Smoker**	**9**	**3**	**7**	**3**	**1**	**1**				**1**	**2**	**2**	**45**
50	Never smoker	4	1	1	4	1	1						2	37
50	**Smoker**	**13**	**5**	**14**	**4**	**1**	**1**					**4**	**2**	**69**
55	Never smoker	8	2	2	6	2	2	1	1			1	2	55
55	**Smoker**	**20**	**6**	**26**	**5**	**2**	**2**	**1**	**1**			**9**	**2**	**110**
60	Never smoker	14	4	3	7	3	3	1	1			2	2	84
60	**Smoker**	**31**	**8**	**41**	**6**	**3**	**3**	**1**	**2**			**18**	**2**	**167**
65	Never smoker	25	7	5	8	5	4	1	2			3	3	131
65	**Smoker**	**45**	**15**	**55**	**7**	**5**	**3**	**1**	**4**			**31**	**3**	**241**
70	Never smoker	46	14	7	9	7	4	1	4			5	4	207
70	**Smoker**	**56**	**25**	**61**	**8**	**6**	**4**	**1**	**7**			**44**	**4**	**335**
75	Never smoker	89	30	7	11	10	5	1	8			6	7	335
75	**Smoker**	**99**	**34**	**58**	**10**	**9**	**4**		**14**			**61**	**7**	**463**

*A never smoker has smoked less than 100 cigarettes in her life and a current smoker has smoked at least 100 cigarettes or more in her life and smokes (any amount) now.
The numbers in each row do not add up the chance of dying from everything combined, because there are many other causes of death besides the ones listed here.

Figure 4. Risk chart for women who currently or have never smoked. The chart indicates the number of women—current smokers (**bold type**) and never smokers—per 1000 who will die from various diseases and from all causes combined during the next 10 years, beginning at the indicated age. **Shaded area** indicates age group and disease combinations with less than 1 death per 1000. COPD = chronic obstructive pulmonary disease.

Risk Chart for Women (former smokers)

Find the line closest to your age. The numbers tell you **how many of 1,000 women will die in the next 10 years from...**

Age	Vascular Disease — Heart Disease	Stroke	Cancer — Lung Cancer	Breast Cancer	Colon Cancer	Ovarian Cancer	Cervical Cancer	Infection — Pneumonia	Flu	AIDS	Lung Disease — COPD	Accidents	All Causes Combined
35	2	1	1	1						1		2	15
40	2	1	2	2						1	1	2	26
45	5	1	3	3	1	1				1	1	2	37
50	7	1	5	4	1	1		1			3	2	52
55	10	3	11	6	2	2	1	1			7	2	80
60	18	5	17	6	3	3	1	1			14	2	125
65	34	9	232	8	5	3	1	3			26	3	191
70	59	18	32	9	7	4	1	5			42	4	302
75	101	34	35	10	9	4	1	10			52	7	452

*A former smoker has smoked at least 100 cigarettes in her life but no longer smokes. The numbers in each row do not add up the chance of dying from everything combined, because there are many other causes of death besides the ones listed here.

Figure 5. Risk chart for women who used to smoke. The chart indicates the number of female former smokers per 1000 who will die from various diseases and from all causes combined during the next 10 years, beginning at the indicated age. **Shaded area** indicates age group and disease combinations with less than 1 death per 1000. COPD = chronic obstructive pulmonary disease.

cancer. After age 50, the chance of dying from lung cancer exceeds the chance of dying from colon or prostate cancer by a factor of about 10. The chance of dying in the next 10 years from COPD is similar to the combined chances of dying from colon and prostate cancer until age 50 but then increases precipitously; by age 70, current smokers have a 45 in 1000 chance of dying from COPD in the next 10 years—more than twice the combined chance of dying from colon and prostate cancer. The effect of smoking on the chance of dying is similar to the effect of adding 10 years of age: for example, a 55-year-old man who smokes has about the same 10-year risk of death from all causes as a 65-year-old man who never smoked (ie, 178 vs 176 of 1000 men will die in the next 10 years).

The large increase in the chance of dying from all causes at older ages among smokers makes it appear that smoking lowers the risk of death for conditions that have no known relationship to cigarette smoking (ie, those for which the relative risk of death for current smokers vs never smokers is 1). For example, the 10-year chance of dying from prostate cancer—a disease that is not associated with cigarette smoking—is higher for a 75-year-old man who never smoked than for one who currently smokes (ie, 19 vs 15 of 1000 men will die in the next 10 years). This finding should not be interpreted as suggesting that smoking protects against prostate cancer or other causes of death in which the same phenomenon occurs (ie, colon cancer or accidents); instead, it simply reflects the impact of smoking on competing risks of death (20). That is, as more current smokers die from smoking-related diseases, fewer current smokers remain who could die of non–smoking-related causes.

Figure 3 is the risk chart for men who are former smokers. For causes of death related to smoking, risks of death for former smokers are intermediate between those of current smokers and those of never smokers.

Risk Charts for Women

Figure 4 displays the risk chart for women who have never smoked and women who currently smoke. At all ages, the chance of dying from all causes combined is lower for women than men with the same smoking status. For women who have never smoked, the magnitudes of the 10-year risks of death from breast cancer and heart disease are similar until age 60; from this age on, heart disease represents the single largest cause of death. Breast cancer is the leading cause of cancer death throughout the lifetimes of women who never smoked.

For women who currently smoke, the chance of dying from heart disease or lung cancer exceeds the chance of dying from breast cancer from age 40 on (and does so by at least a factor of 5 after age 55). By age 50, the chance of dying from lung cancer exceeds the chance of dying from heart disease (14 vs 13 of 1000 women will die in the next 10 years). The effect of smoking on the chance of dying is similar to the effect of adding 5 to 10 years of age: the 10-year chance of dying from all causes combined for a 55-year-old woman who smokes is somewhere between that of a 60-year-old woman who never smoked and a 65-year-old woman who never smoked (110 vs 84 and 131 of 1000 women, respectively, will die in the next 10 years).

The spurious "protective" effect of smoking at older ages that is present in men is also present in women but is less dramatic.

Because of large competing risks of death from smoking-related diseases at age 65 or older, women who smoke generally appear to have a slightly lower chance of dying from breast, colon, or ovarian cancer than women who have never smoked, despite the lack of any known associations between smoking and these cancers.

Figure 5 is the risk chart for women who are former smokers. For causes of death related to smoking, risks of death for former smokers are intermediate between those of current smokers and those of never smokers.

Sensitivity Analysis

In analyses to address potential confounding of the smoking-associated relative risks from CPS-II by socioeconomic status, we found that reducing the relative risks by as much as 25% (eg, from 2.0 to 1.5) had little effect on our results. On average, the calculated 10-year chance of death was reduced by less than 10% for both men and women smokers.

Discussion

We created simple charts with age-, sex-, and smoking-specific data about the chance of dying from various common causes in the next 10 years. The charts are designed to put the chance of dying from a given disease in the context of the chances of dying from other diseases and of dying from all causes. The current risk charts represent a substantial improvement over the risk charts that we previously published (3). The new risk charts use more recent data and age-specific relative risks and employ a different method to account for smoking status (the earlier method combined former and never smokers, which distorted some risks; the new algorithm treats never, former, and current smokers as separate groups).

We want to acknowledge three methodologic limitations of the charts. First, cause-specific death rates require accurate attribution of death. Although we used the 2004 Multiple Cause of Death Public Use File from the NCHS, the best available (and most recent) national source of mortality data, these data are derived from death certificates. Death certificates are not always accurate nor is the determination of the underlying cause of death (13). Nonetheless, death certificates are the standard source of mortality data in the United States (21). Second, our charts depend on the accuracy of the relative risks from CPS-II. Concerns have been raised about residual confounding by socioeconomic factors (19). However, our sensitivity analyses showed that reducing these relative risks by as much as 25% (ie, moving the relative risks toward 1) had only a small effect on the chance of death. Moreover, the CPS-II relative risks are the inputs used by the Centers for Disease Control (22) and the US Surgeon General (16) to estimate "smoking attributable deaths."

Third, we did not attempt to provide more personalized risk estimates. More personalized estimates, that is, estimates that account for important disease risk factors, such as a strong family history of a certain disease or various behaviors or exposures, would be useful if they generated reliable predictions (23). However, good mortality-specific risk prediction models are not available for most diseases [lung cancer mortality being a notable exception (24)]. Furthermore, personalized estimates add practical complexities to implementation. For example, personalized

estimates would probably require a computer interface that allows users to enter the requisite information; alternatively, users would have to navigate multiple complex tables to find the right estimates. In fact, we believe that the simplicity of our charts represents a distinct advantage over interactive computer applications: the charts are inexpensive, can be used anywhere, and require no special hardware or trained personnel. Moreover, our charts account for what are arguably the three most important risk factors for death: age, sex, and smoking.

The risk charts provide two basic elements that people need if they are to make sense of the health threats they face: the magnitude of the risk and some context. We hope that the availability of these simple charts will facilitate physician–patient discussion about disease risk and help people understand where to focus risk reduction efforts. The charts are posted electronically in a variety of formats (ie, as presented in this paper, as separate charts for each smoking category, and as single-page charts presenting all the data in one place for men and women; see Supplementary Figures 1–10, available online). We encourage physicians (and others) to post the charts in clinic offices or distribute them to patients for easy reference when decisions (such as cancer screening) are being made.

Finally, the charts provide a compelling demonstration of the harms of cigarette smoking—the effect of smoking on mortality risk is like adding 5 to 10 years of age. After publication of the first set of charts, we received many messages from patients, providers, and colleagues suggesting that the charts may be especially useful in smoking prevention and cessation efforts. Regardless of how the charts are used, we believe that they will provide a much-needed perspective on health risks.

Appendix 1. Definitions for Specific Causes of Death Included in Risk Charts*

Condition	ICD-10 definition
Vascular disease	
Heart disease	
Ischemic heart disease	I20–I25
Congestive heart failure	I50
Cardiomyopathy	I42.0, I42.8, I42.9
Arrhythmia	I44–I49
Stroke	I60–I69
Cancer	
Breast cancer	C50
Cervical cancer	C53
Colon cancer (includes rectum/anus)	C18–C21
Lung cancer (trachea/bronchus/lung)	C33–C34
Ovarian cancer (includes unspecified genital organs)	C56–C57
Prostate cancer	C61
Infection	
Pneumonia (viral/bacterial/unspecified organism)	J12–J18
Flu	J10–J11
AIDS	B20–B24
COPD (does not include asthma)	J40–J44
Accidents (unintentional injuries)	V01–X58, Y85–Y86

* ICD-10 = *International Classification of Diseases, Tenth Revision* (available at http://www.who.int/classifications/icd/en/); COPD = chronic obstructive pulmonary disease.

Appendix 2. Example of Risk Chart Calculation: Calculation of the 10-Year Risk of Lung Cancer Death for 70-Year-Old Men Who Currently Smoke

1. Calculate age-, sex-, and cause-specific death rate for lung cancer death for 70-year-old men:
Age-, sex-, cause-specific death rate = men age 70 dying from lung cancer in 2004/men age 70 alive in 2004 = 2867/788 967 = 0.0036338,
where the numerator comes from the NCHS Multiple Cause of Death File (2004) and the denominator comes from the US Census "bridged" estimated midyear (July 7, 2004) population.

2. Determine age-, sex-, and cause-specific death rate for 70-year-old men who have never smoked, where

Deaths$_{TOTAL}$ is total number of cause specific deaths.
N$_{TOTAL}$ is the total population at risk
%NS is the proportion of the total population who are never smokers
%FS is the proportion of the total population who are former smokers
%CS is the proportion of the total population who are current smokers
rate$_{NS}$ is the annual age-, sex- specific death rates for never smokers
rate$_{FS}$ is the annual age-, sex- specific death rates for former smokers
rate$_{CS}$ is the annual age-, sex- specific death rates for current smokers
RR$_{FS/NS}$ is the relative risk of death for former vs never smokers
RR$_{CS/NS}$ is the relative risk of death for current vs never smokers
The age-, sex-, cause-specific death rate is

= Deaths$_{TOTAL}$/N$_{TOTAL}$ for that age-, sex- specific group

which can also be expressed as the average of the rates of never, former and current smokers weighted by their proportion in the population:

= %NS × rate$_{NS}$ + %FS × rate$_{FS}$ + %CS × rate$_{CS}$

Because our goal is to solve for rate$_{NS}$, it is necessary to express rate$_{FS}$ and rate$_{CS}$ in terms of rate$_{NS}$. This is possible because the terms are related through the relative risks:

RR$_{FS/NS}$ = rate$_{FS}$/rate$_{NS}$; so the rate$_{FS}$ = rate$_{NS}$ × RR$_{FS/NS}$; and
RR$_{CS/NS}$ = rate$_{CS}$/rate$_{NS}$; so the rate$_{CS}$ = rate$_{NS}$ × RR$_{CS/NS}$
Substituting these terms into the original equation:

Deaths$_{TOTAL}$/N$_{TOTAL}$ = %NS × rate$_{NS}$ + %FS × (rate$_{NS}$ × RR$_{FS/NS}$) + %CS × (rate$_{NS}$ × RR$_{CS/NS}$)

Rearranging the terms:

Deaths$_{TOTAL}$ = rate$_{NS}$ (%NS + (%FS × RR$_{FS/NS}$) + (%CS × RR$_{CS/NS}$)) × N$_{TOTAL}$

Then solving for the rate$_{NS}$:

rate$_{NS}$ = Deaths$_{TOTAL}$/{N$_{TOTAL}$ × [(%NS + (%FS × RR$_{FS/NS}$) + (%CS × RR$_{CS/NS}$)]}

Substituting values for 70-year-old men, the lung cancer death rate for never smokers is

rate$_{NS}$ = 2867/[788. 967 × (33.6% + 53.5% × 7.62 + 12.9% × 23.41)]
= 0.000489.

Calculate the age-, sex-, and cause-specific death rate for 70-year-old men who currently smoke. This is done by rearranging the terms in the relative risk formula:

RR$_{CS/NS}$ = rate$_{CS}$/rate$_{NS}$; rate$_{CS}$ = RR$_{CS/NS}$ × rate$_{NS}$.

Substituting values for lung cancer among 70-year-old men:

rate$_{CS}$ = 23.41 × 0.000489 = 0.01145.

Accumulate 10-year risk of death for age-, sex-, and cause-specific groups using life tables. Here is the life table for 70-year-old men who currently smoke (to get former smokers, repeat step 3, but use relative risk for former smokers vs never smokers).

Age	No. alive at start of year* (A)	Annual lung cancer death rate (B)	No. of lung cancer deaths (A × B)	Annual rate of deaths from all causes (C)	No. of deaths from all causes (A × C)
70	100 000	0.01145	1144.8	0.04532	4532
71	95 468	0.01168	1114.9	0.04879	4658
72	90 810	0.01276	1159.0	0.05288	4802
73	86 008	0.01351	1161.7	0.05855	5035
74	80 972	0.01376	1114.4	0.06243	5055
75	75 918	0.01589	1206.0	0.06987	5304
76	70 613	0.01696	1197.6	0.07593	5362
77	65 251	0.01756	1145.8	0.08323	5431
78	59 820	0.01751	1047.2	0.09238	5526
79	54 294	0.01766	958.9	0.09922	5387
Totals			11250.3		51093
10-year risks		11250.3 per 100 000= 113 per 1000		51 093 per 100 000= 511 per 1000	

* Number alive at the start of year (ie, the population at risk) = number alive at start of previous year – all-cause deaths during the previous year.

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